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APPARATUS AND METHOD FOR DETECTION OF SIGNALS

The present invention relates to method and apparatus for detection of signals, particularly in a cellular communications network requiring location information and fast hand-off operation.

In cellular communications networks such as IS95, a mobile terminal in communication with a base station enjoys closed and open loop transmit power control. This effectively means that the mobile terminal transmission powers are optimised such that, at the serving base station, the received signal levels are at a substantially constant minimum level for adequate detection, set by the desired quality of the communications link. If the mobile terminal is in communication with more than one serving base station, e.g. during soft hand-off period, the combined power or the strongest received signal (or a combination of the above two techniques) is kept to a substantially constant minimum level of adequate detection set by the desired quality of the communications link. The power control mechanism ensures that the multiple access interference, caused by a mobile terminal, within or outside the cell covered by the serving base station is kept to a minimum.

Although power control is desirable and even essential

in systems such as direct sequence spread spectrum code division multiple access (DS-CDMA), it reduces the ability of base stations, not serving a given mobile terminal, to receive and detect the mobile terminal transmissions adequately and reliably. The reliable detection of mobile terminal transmissions by base stations other than the serving base stations is desirable for services such as "location" and for "hand off" operations. It is therefore desirable to increase the detection ability of non-serving base stations without any increase in mobile terminal transmission power, so that information such as propagation time delay (i.e. distance) and mobile terminal signal power strength are available with a received signal well below the minimum required level for adequate information data detection.

The present invention sets out preferably to increase the detection ability of a mobile terminal transmitted signal by a cellular communications network, or signal transmitted by a first and second base stations and detected by a mobile terminal.

According, a first aspect of the present invention provides a method of detection of signals in a communication network (e.g. cellular) including a mobile terminal, at least one first base station serving the mobile terminal and at least one second base station wherein the method includes mobile transmitted data detected at the first base station

being used by the second base station to increase detection probability of the transmitted data by the second base station.

Preferably, the signal received by the first base station is of sufficient quality to enable detection of the data transmitted by the signal. More preferably the detected data is used by the second base station(s), where the mobile terminal transmissions are not received with sufficient power for adequate detection, to enable detection of the data by the second base station(s).

The detection process of the second base station(s) may be based on serial correlation, matched filter correlation, maximum likelihood sequence estimation, joint-detection or multiuser detection or any combination of these.

The detection process at the second base station(s) preferably includes detection of the presence of the data detected at the first base station(s).

The detection process at the second base station(s) preferably includes detection and calculation of the received time delay caused by signal propagation due to the distance of the mobile terminal from the respective base station.

The detection process at the second base station(s) may

additionally or alternatively include detection of the received signal power of the mobile terminal transmission signal by the second base station(s).

Preferably the mobile terminal is served by the first base station over a communications channel. More preferably, the communications channel is a traffic channel, an access channel or a control channel, which can be operated in a packet or circuit switched mode.

The cellular communications network is preferably a direct sequence spread spectrum code division multiple access (DS-CDMA) system and the data is preferably used to extend and increase the processing gain of the receiver by enabling longer integration times at the base stations. More preferably the network system is a GSM or GSM derivative system.

The location of the mobile terminal may be determined from the network system by e.g. using the received time delay at each respective base station, using the direction of the mobile terminal from each respective base station, or a combination of received time delay and/or direction of the mobile terminal from a first base station(s) and received time delay and/or direction of the mobile terminal from a second base station(s).

The process of determining the location of the mobile terminal using three or more fixed base stations of

known position is known in the art as triangulation or trilatituration.

Preferably, the data received by at least the first base station is capable of identifying the mobile terminal in the network system.

The measured signal power of the mobile terminal may be used for hand-off preparation from a first base station to a second base station.

Preferably the data transmitted by the mobile terminal is unknown information data.

Alternatively, or additionally, preferably the data transmitted by the mobile terminal is a predefined sequence.

The data received by the first base station may be used by that station as well as or instead of the second base station to improve detection of the transmitted data by the mobile station.

Preferably, Spatial filtering is used at the second base station(s) to reduce the effect of the propagation channel(s) on the received signal.

A second aspect of the invention provides a system for detection of signals in a communications network (e.g. cellular) including a plurality of base stations and a

mobile terminal wherein at a given time at least one of the base stations is a serving base station and the mobile terminal is served by the serving base station; the serving base station is capable of receiving and detecting data transmitted to it by the mobile terminal and the detected data is usable by the serving base station and/or at least one other base station to increase detection probability of the transmitted data.

An embodiment of the present invention will now be described by way of example only referring to the accompanying drawings in which:

Figure 1 is a schematic drawing of a general embodiment of the invention.

Figure 2 is a schematic drawing showing the components of part of a first base station of an embodiment of the invention.

Figure 3 is a schematic drawing showing the components of part of a second base station of an embodiment of the invention.

Figure 4 is a graphical representation of a data frame structure typically transmitted by the first and second base stations.

Figure 5 is a schematic drawing showing the components of a scrambler for scrambling and spreading the data

frame shown in Figure 4.

Figure 6 is a graphical representation of a data frame structure typically transmitted by the mobile terminal.

Figure 7 is a schematic drawing showing the components of a scrambler for scrambling and spreading the data frame shown in Figure 6.

Figure 8 is a flow diagram showing the operative steps of the part of the first base station shown schematically in Figure 2.

Figure 9 is a flow diagram showing the operative steps of the part of the second base station shown schematically in Figure 3.

A cellular system 100 (Fig. 1) installed in a geographical area, for example, a city centre 102 comprises a first base station 104 having a first associated coverage area 106 and a second base station 108 having a second associated coverage area 110, and a third base station 107 and associated coverage area 111.

The first, the second and the third base stations 104, 108, 107 are independently connected to a base station controller (BSC) 112, the BSC 112 being connected to a mobile switching centre (MSC) 114. The MSC 114 is in communication with a fixed terminal 116 via a public

switched telecommunication network (PSTN) 118.

An example of the first, the second and the third base stations 104, 108,107 are units of Supercell (trade mark) base stations manufactured by Motorola. The Supercell base stations have appropriate hardware and/or software modifications so as to be capable of functioning with time delay estimation units 220, 320. A mobile terminal 120 is located within the first coverage area 106 and the second coverage area 110. However, it is not essential for the mobile terminal 120 to be located within the second coverage area 110. The mobile terminal 120 can be located in the vicinity of the second and third coverage areas 110,111.

4 As example of the mobile terminal 120, is a Qualconn QCP/820 model cellular telephone.

Referring to Fig. 2, the first base station 104 comprises a receiver chain 200. The receiver chain 200 has an antenna 202 coupled to a low noise amplifier 204. The low noise amplifier 204 being coupled to a bandpass filter 206. The bandpass filter 206 is coupled to a mixer 208. The mixer 208 being coupled to a lowpass filter 212 and a synthesiser unit 210. The lowpass filter 212 is coupled to an analogue to digital converter (ADC) 214 which is coupled to a digital signal processor (DSP) 218 via a buffer 216.

The buffer 216 is also coupled to delay estimation unit

220. The delay estimation unit 220 is also coupled to the DSP 218. Within the delay estimation unit 220, the buffer output is coupled to a multiplier 222. The multiplier 222 is coupled to an integrator 224 and a variable delay unit 226. The integrator unit 224 is coupled to a peak detector 230, and is to integrate received data over a transmitted symbol period Ts, which is set to an initial value of zero at the beginning of each correlation operation i.e. starting at the beginning of each received data symbol. The output of the peak detector 230 is coupled to processor 232. The variable delay unit 226 is coupled to both processor 232 and the code unit 228. Finally, the clock 234 is coupled to processor unit 232. The clock 234 is also coupled to code unit 228.

The receiver is operating with both in phase and quadrature phase components present (i.e. complex data).

The above described receiver chain 200 is shown for exemplary purposes only and can also form a part of a transceiver circuit (not shown).

Referring to Fig. 3., the second and third base stations 108, 107 each include a receiver chain 300. The receiver chain 300 has an antenna 302 coupled to a low noise amplifier 304. The low noise amplifier 304 being coupled to a bandpass filter 306. The bandpass filter 306 is coupled to a mixer 308. The mixer 308

being coupled to a lowpass filter 312 and a synthesiser unit 310. The lowpass filter 312 is coupled to an analogue to digital converter (ADC) 314 which is coupled to a buffer 316. The buffer unit is coupled to a delay estimation unit 320. Within the delay estimation unit 320, the buffer output is coupled to a multiplier 322.

The multiplier 322 is coupled to an integrator 324 and a variable delay unit 326. The integrator unit 324 is also coupled to a peak detector 330. The integrator 324, having been set to an initial value of zero at the beginning of each correlation operation i.e. at the beginning of a received data block, is to integrate received data for a desired period Ti. The output of the peak detector 330 is coupled to a processor 332. The variable delay unit 326 is coupled to multiplier 329 and is also coupled to processor 332. A clock 334 is coupled to processor 332. The multiplier 329 is coupled to both a DSP unit 319 and a code unit 328. The DSP unit is coupled to information data unit 318. The clock 334 is also coupled to the code unit 328.

The receiver chain is operating with both in phase and quadrature phase components present (i.e. complex data).

The above described receiver chain 300 is shown for exemplary purposes only and can also form a part of a transceiver circuit (not shown).

The first, the second and the third base stations 104, 108, 107 are all capable of transmitting a sequence of 20 msec data frames having a data frame structure 400 (shown in Figure 4). The data frame 400 has a structure comprising information data portions 436, 438, 440, 442, 444, 446, 448, 450, 452, 454, 456, 458, 460, 462, 464, 466, 468. The frame structure 400 also comprises 16 power control data portions, 404, 406, 408, 410, 412, 414, 410, 418, 420, 422, 424, 426, 428, 430, 432, 434.

The data frame 400 is scrambled and spread by scrambler code 500. Spreading is, to broaden the signalling bandwidth of the data frame 400. The scrambler includes several codes 504, 506, 508, 510, known to all network components, ie. base stations 104, 108 and 107 and mobile terminal 120.

Referring to Fig. 5. The data is scrambled and spread by LC code 504, at multiplier 512. The data is further scrambled by Walsh code 506 at multiplier 514. The resulting scrambled data is then, once scrambled by I code 510 for in phase transmission at multiplier 516, and once by Q code 508 for quadrature phase transmission at multiplier 518. The resulting scrambling and spreading code is referred to, for this example, as scrambling code 502.

The scrambling code 502 is used for calculation of various parameters, for example channel estimation,

frame synchronisation and coherent detection of data. The mobile terminal 120 operations are synchronised to the scrambling code 502.

The mobile terminal 120 is capable of transmitting a sequence of 20 msec data frames having a data structure 600. The data frame 600 consists mostly of information data portion.

The data frame 600 is scrambled and spread by scrambler 700. Spreading is, to broaden the signalling bandwidth of the data frame 600. The scrambler 700, includes several codes 704, 708, 706 known to all network components, i.e. base stations 104, 107 and 108 and mobile terminal 120.

Referring to Fig. 7. The data is scrambled and spread by LC code 704 at multiplier 710. The resulting scrambled and spread data is then once scrambled by I code 708 for in phase transmission, at multiplier 712, and once by Q code 706 for quadrature phase transmission at multiplier 714. The resulting scrambling and spreading code is referred to, for this example, as scrambling code 702.

The operation of the above cellular system 100 will now be described below.

A call is established according to any known method in the art. The first base station 104 being in

communication with the mobile terminal 120 and a first traffic channel (tch) is allocated. Data frames having the structure of the first data frame structure 400 are transmitted from first base station 104 and received by mobile terminal 120. Data frames having the structure of the second data frame structure 600 are transmitted from mobile terminal 120 and received by first base station 104. The first base station 104 by means of power control data 404, 406, 408, 410, 412, 414, 416, 418, 420, 422, 424, 426, 428, 430, 432, 434 controls the transmit power of the mobile terminal 120 according to techniques well known in the art. The data frames 600 received by the first base station antenna 202 are of only sufficient power for correct detection of propagation time delay and information data by the first base station 104. By information data, it is meant the <u>unknown</u> information data which is present in the data frames 400 and data frames 600.

Hence the mobile terminal 120 transmit power, is of sufficient magnitude to overcome the propagation losses to the first base station 104 only. The second and the third base Stations 108, 107 not in communication with the mobile terminal 120 may suffer excessive propagation losses such that they are unable to receive the transmitted data frames 600 by the mobile terminal 120, with sufficient power for reliable and successful detection of time delay and information data.

A method of detection of information data 828 and time

delay 824 for the first base station 104 is outlined in Figure 8 and is as follows. The synthesiser 210 of the first base station 104 is tuned to receive a data frame 600 at the expected time of arrival, transmitted from the mobile terminal 120 (step 802). As traffic data frame 600 is received, in the specified time frame, by the first base station 104, the traffic data is stored (step 806).

The first base station 104 then determines (step 808) whether sufficient time has elapsed to receive the entire data frame 600. Considering the longest propagation time delay expected, due to distance between the first base station 104 and the mobile terminal 120. If sufficient time has not elapsed, the first base station 104 continues to receive and store the traffic data (step 806). When the specified time has elapsed, the first base station 104 initialises the expected time delay (T) to zero (step 810).

The descrambling code which is similar to scrambling code 702 at the time of transmission of the data frame 600 by the mobile terminal 120 (which is known in the art as code synchronised) is then delayed by the specified time delay T (step 812). The first base station 104 descrambles the received data traffic with the delayed descrambling code 702 (step 814). The descrambled data traffic is then summed (integrated) over a data symbol period Ts (step 818).

If no substantial peak is detected by the first base station 104, the expected time delay T is increased (by a set amount) (step 820) and the steps 812, 814, 816, 818 and 820 are repeated until a substantial peak is detected. After the detection of a substantial peak, the first base station 104, calculates and stores the time delay and further calculates the distance from the mobile terminal 120 (step 822).

In the presence of multipath propagation, several peaks may be detected, where one or more peaks can be used for data detection.

After the successful estimation of the time delay between the first base station 104 and the mobile terminal 120, the correct portion of the received traffic data is selected at the data frame portion 600, transmitted by the mobile terminal 120 (step 826), the information data contained in the data frame 600 is then detected and stored (step 828).

The time delay and the distance between the first base station 104 and the mobile terminal 120 are sent to MSC 114, and stored.

A method of detection of time delay for the second base station 108 is outlined in Figure 9 and is as follows.

The synthesiser 310 of the second base station 108 is tuned at the expected time of arrival of data frame 600

to receive the data frame 600, transmitted from the mobile terminal 120 (step 902). As traffic data is received, in the specified time, by the second base station 108, the traffic data is stored (step 906).

The second base station then determines (step 908) whether sufficient time has elapsed to receive the entire data frame 600, allowing for the longest expected propagation time delay caused by the distance between the second base station 108 and the mobile terminal 120. If sufficient time has not elapsed, the second base station 108 continues to receive and store the traffic data (step 906). When the specified time has elapsed, the second base station 108 obtains and stores information data 318 detected and stored at step 828, by the first base station 104, via network elements, e.g. BSC 112 (step 910).

The second base station 108 then processes 319 the stored information data 318 and scrambles it with scrambling code 702, 328 in a similar manner to the processing and scrambling performed by the mobile terminal 120 on the original information date, prior to transmission of data frame 600 and stores it (step 912). After step 912, the stored processed and scrambled information data, referred to now as "data descrambling code" is substantially similar in envelope and phase to the transmitted data frame 600 by the mobile terminal 120.

The second base station 108 then proceeds to initialise the expected time delay T to zero (step 916). The "data descrambling code" is then delayed by the specified delay T (step 918). The second base station 108 descrambles the received data traffic with the "data descrambling code" (step 920). The descrambled data traffic is then summed (integrated) over sufficient long time, Ti to ensure reliable and successful detection of mobile terminal 120 transmitted data frame 600 (step 922). Ti is long enough to provide sufficient noise bandwidth reduction, thus providing sufficient signal-to-noise ratio gain, known in the art as "processing gain", to account for all possible excess propagation losses experienced by the second base station 108, compared to that experienced by the first base station 104.

The second base station 108 then determines whether a substantial peak is detected as a result of the summation (step 928). If no peak is detected by the second base station 108, the expected time delay T is increased (step 924), and the step 918, 920, 922, 926 and 924 are repeated until a substantial peak is detected. After the detection of an acceptable peak, the second base station 108 calculates and stores the time delay and further calculates the distance the mobile terminal 120 is from the second base station 108 (step 928).

The third base station 107 operates a method of

detection of time delay substantially identical to that explained above for the second base station 108.

The time delay and distance between the second base station 108 and the mobile terminal 120 are sent to MSC 114 and stored. The time delay and distance between the third base station 107 and the mobile terminal 120 are sent to MSC 114 and stored. The MSC 114 uses, by a method known in the art as triangulation, the stored data on the distance of the mobile terminal 120 from the first and second and the third base stations 104, 108, 107 the known coordinates of the first, the second and the third base stations 104, 108, 107 to estimate the coordinates of the mobile terminal 120.

The remaining components of a cellular communication system base station are well known in the art and need not be described in detail herein.

The above embodiments of the present invention have been described by way of example only and various alternative features or modifications from what has been described can be made within the scope of the invention, as will be readily apparent to persons skilled in the art.